UNIT M1- DIESEL ENGINE FUNDAMENTALS AND WORKING PRINCIPLES

OBJECTIVE

The objective of this unit is to make you understand about the basic working principle and fundamentals of Diesel Engine as per the following details: -

- Working principle
- Classification of Diesel Engine based on cycle of operation, aspiration, Cylinder arrangement and Engine Layout, speed and power output.
- Understanding working cycle through valve timing diagram.
- Understanding process of combustion in Diesel Engine.

STRUCTURE

- Introduction
- Cycle of Operation
- Valve Timing Diagram
- Cylinder arrangement and Engine Layout.
- Natural aspiration and Supercharging
- Firing Order
- Combustion in Diesel Engine
- WDM2 Diesel Locomotive Engine Data and Layout
- Summary
- Self assessment

INTRODUCTION

As commonly known, there are two types of engines i.e. External Combustion Engine and Internal Combustion Engine. The examples of External Combustion Engine are Coal or oil fired steam engines and those of Internal Combustion engine are Petrol, Diesel and Gas engine.

In External Combustion engine, coal or liquid fuel is burnt outside the cylinder, but in Internal Combustion engine the fuel burns inside the cylinder.

The Internal Combustion engines are again divided into two groups i.e.(i) Spark Ignition engines and (ii) Compression Ignition engine, Example of spark ignition engine is petrol and gas engine where-as example of compression ignition engine is diesel engine.

The basic purpose of an IC engine is to develop power by burning fuel. Therefore, good performance of an Engine is dependent on how quickly and completely the fuel can be burnt. This burning of hydrocarbons is called combustion, which is a chemical process (oxidation), accompanied by emission of light and heat.

The petrol or gas engines are called spark ignition engines, as electric spark is required for ignition of fuel air mixture, which is injected in the mixture form in the combustion chamber.

The process of combustion in the compression ignition engine differs widely from that of spark ignition engine. In case of diesel engine only fuel in liquid state is injected at very a high pressure, into highly heated and compressed air in the combustion chamber, the heat of the compressed air starts the combustion process and no agency like electric spark is required.

The name 'Compression Ignition Engine' has been derived from the fact that the air drawn in the suction stroke is compressed to such a degree in compression stroke, that the heat generated due to compression goes much above the self ignition or auto-ignition temperature of the liquid fuel.

The abbreviation `IC Engine' (Internal Combustion Engine) and C.I.Engines (Compression Ignition Engine) sometimes causes confusion. Though both petrol and diesel engines are `I.C.Engines', only diesel engines work on Compression Ignition principle and should be termed as `C.I.Engines'. In other words while all `C.I.Engines' are `I.C.Engines' but all `I.C.Engines' are not `C.I.Engines'.

Compression Ratio

The compression ratio of `I.C.Engines' is the ratio between total volume i.e. (clearance volume + swept volume.) and clearance volume

In other words this ratio is indicative of the degree of compression of the trapped air. Higher the compression ratio, higher will be the compression pressure and consequently higher the temperature.

It is for this reason that compression ratio of spark ignition engine is lesser (round about 8:1) whereas the compression ratio of compression ignition engine is 12:1 & above.

CYCLE OF OPERATION

In any Compression Ignition engine following pre-requisites must be fulfilled.

(a) Suction or Induction

The suction or induction of fresh cool air must take place for the purpose of providing oxygen for combustion of fuel as also for the scavenging of burnt gases and taking away heat from the combustion chamber components.

(b) Compression:

Once the air is drawn in, the air inlet passage is closed. The trapped air is compressed due to upward movement of pistons. Once the air is highly compressed, it attains high temperature. At this stage fuel is injected just before the T.D.C. for combustion to start.

(c) Firing or Power:

Very shortly after the fuel injection, the firing takes place and peak pressure is achieved just after TDC, the expansion of gas provides the force or power which drives the piston back, thus rotating the crank shaft.

(d) Exhaust:

After the fuel is burnt out, the burnt gas has to find passage to atmosphere so that space can be made for accommodating fresh air for the next cycle of operation.

The aforesaid requirements are fulfilled in either four strokes of piston or in 2 strokes. In case of the former the engine is called a four stroke cycle engine and in case of the latter the engine is called two stroke cycle i.e. either two revolutions or one revolution of the crankshaft cover all the events of the cycle.

FOUR STROKE/ TWO STROKE CYCLE

While in four stroke cycle engines, suction, compression, fuel injection, exhaust and scavenging, are completed in four strokes of the piston or two revolutions of the crank, in two stroke engines all these are completed in two strokes of the piston or one revolution of the crankshaft.

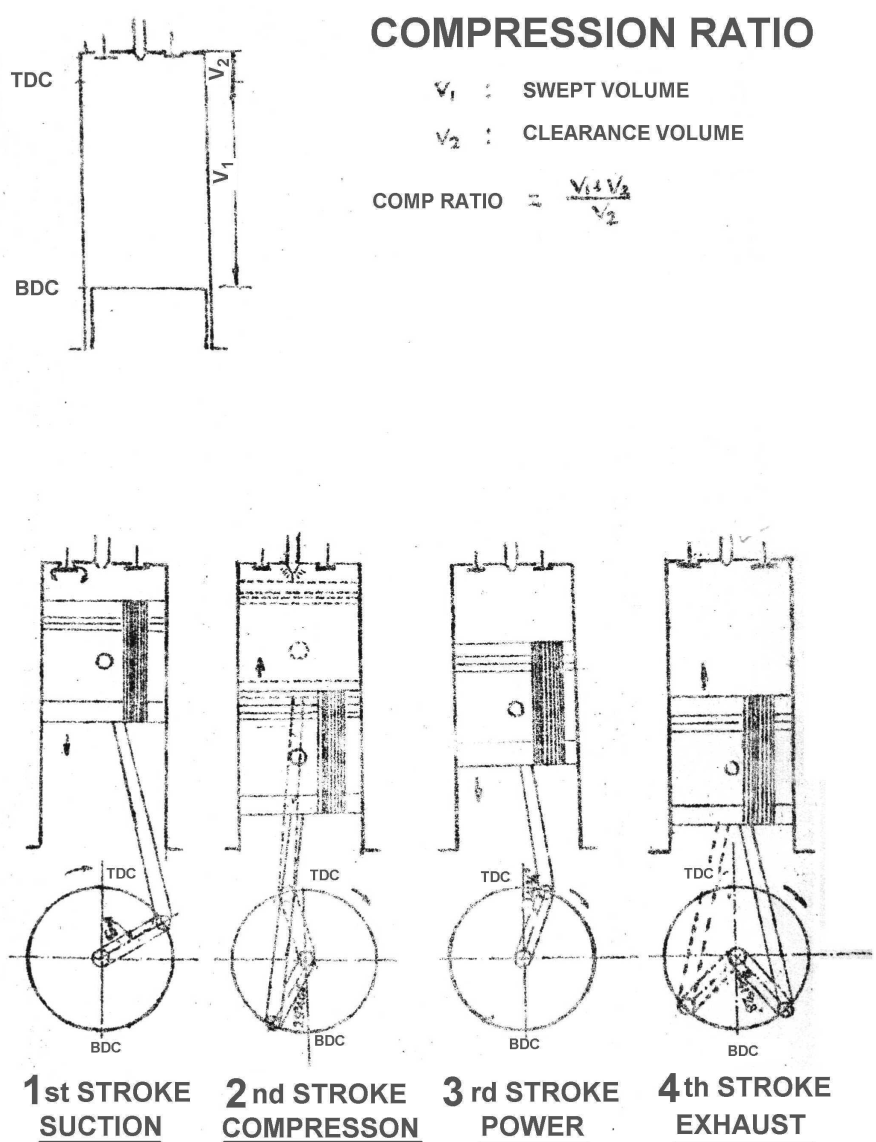
(Sk.1.1. & Sk.1.2.)

There are various designs of 2 stroke cycle engines but one thing common in all, is that compressed air is essential for the purpose of scavenging right from the lowest power output whereas in case of 4 stroke cycle engine at lower power range it works as naturally aspirated engine.

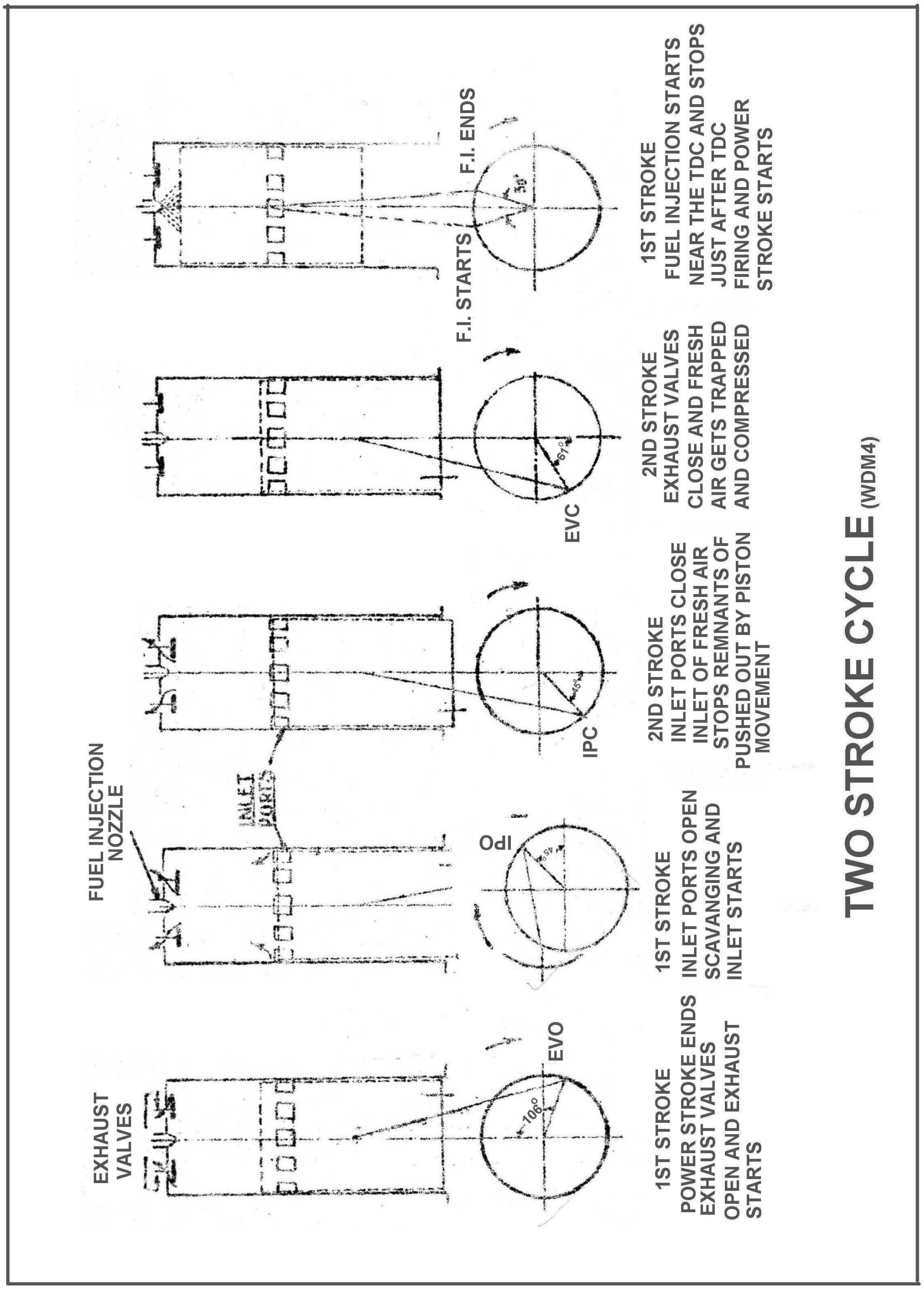
To describe this process in greater detail, we can take the example of the WDG4 locomotive, in which all the exhaust valves are in the cylinder head at the top and the inlet ports are round the cylinder liner.

VALVE TIMING DIAGRAM

Valve Timing Diagram of 2 stroke (WDG4/ GM Engine) and 4 Stroke (WDM2 Engine) is being dealt separately for better understanding.


COMPRESSION RATIO
TDC
BDC
V_2
V_1
V_1 : SWEPT VOLUME
V_2 : CLEARANCE VOLUME
COMP RATIO = $\frac{V_1 + V_2}{V_2}$
TDC
BDC
1st STROKE
SUCTION
2nd STROKE
COMPRESSON
3rd STROKE
POWER
4th STROKE
EXHAUST

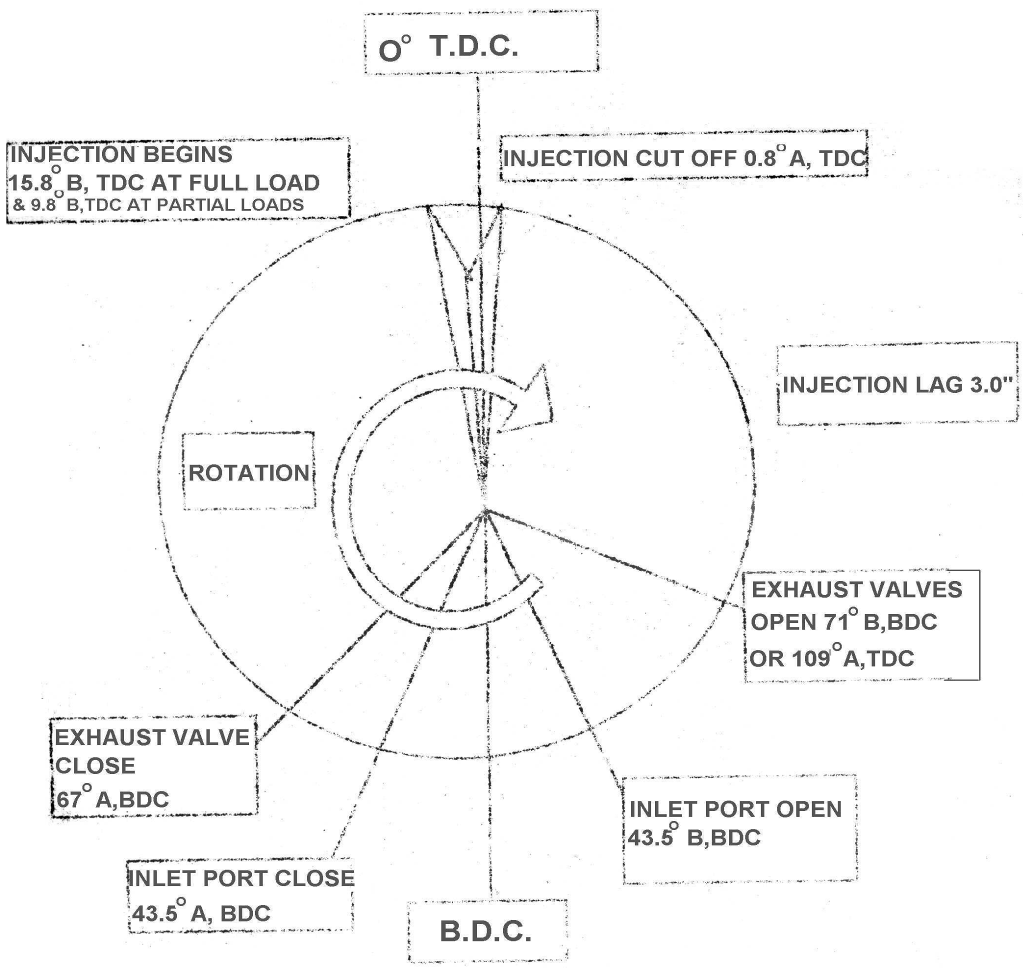
Sk: 1.1



EXHAUST VALVES
FUEL INJECTION NOZZLE
INLET PORTS
EVO
106°
IPO
45°
IPC
45°
EVC
67°
F.I. STARTS
F.I. ENDS
30°
1ST STROKE
POWER STROKE ENDS
EXHAUST VALVES
OPEN AND EXHAUST
STARTS
1ST STROKE
INLET PORTS OPEN
SCAVANGING AND
INLET STARTS
2ND STROKE
INLET PORTS CLOSE
INLET OF FRESH AIR
STOPS REMNANTS OF
PUSHED OUT BY PISTON
MOVEMENT
2ND STROKE
EXHAUST VALVES
CLOSE AND FRESH
AIR GETS TRAPPED
AND COMPRESSED
1ST STROKE
FUEL INJECTION STARTS
NEAR THE TDC AND STOPS
JUST AFTER TDC
FIRING AND POWER
STROKE STARTS
TWO STROKE CYCLE (WDM4)

Sk: 1.2

VALVE TIMING DIAGRAM (710 G3-B, GM ENGINE)



Sk: 1.3

VALVE TIMING- TWO STROKE CYCLE (sk: 1.3)

Just before the TDC, the fuel injection starts and the power stroke begins just after the TDC. After the piston has moved down partly, and the crank is at a position of 109^O from the TDC, or 71^O from the BDC, the exhaust valves open allowing the exhaust to escape. With the escape of the part of exhaust gas, the pressure in the combustion chamber falls. By this time the piston has gone further down, and when the crank comes to 43.5^O before TDC, the piston uncovers inlet port on the sides, and scavenging air finds access into the cylinders and tries to push out the exhaust gases. This process continues upto 43.5^O after the BDC. Thus for a period of 87^O , both exhaust valves and the inlet ports remain open. After 43.5^O after the BDC, the inlet ports close, but the exhaust ports still remain open. At this time, the lower port of the combustion chamber is full of fresh air, and the upper port is filled with a mixture of burnt gas and air. With further movement of piston in the upward stroke, the piston has moved further, bringing the crank to about 67^O after the BDC, and the exhaust valves close. The trapped gas contains mostly pure air, and compression takes place. While compression is taking place at about 15.8^O before the TDC, the fuel is injected at a high pressure against hot compressed air. The firing starts with peak pressure being reached just after the TDC. From the above, it is seen that in the first or downward stroke, this type of engine, following takes place-

A combustion of fuel, giving power, forcing the piston to go down.

B exhaust of the burnt gas starts at 109^O after TDC or 71^O before BDC.

C scavenging and inlet of fresh air starts at 43.5^O before BDC.

Therefore, only a part of the downward stroke is power stroke, and the rest is taken up by the exhaust and scavenging. Similarly, in the upward stroke, the following takes place.

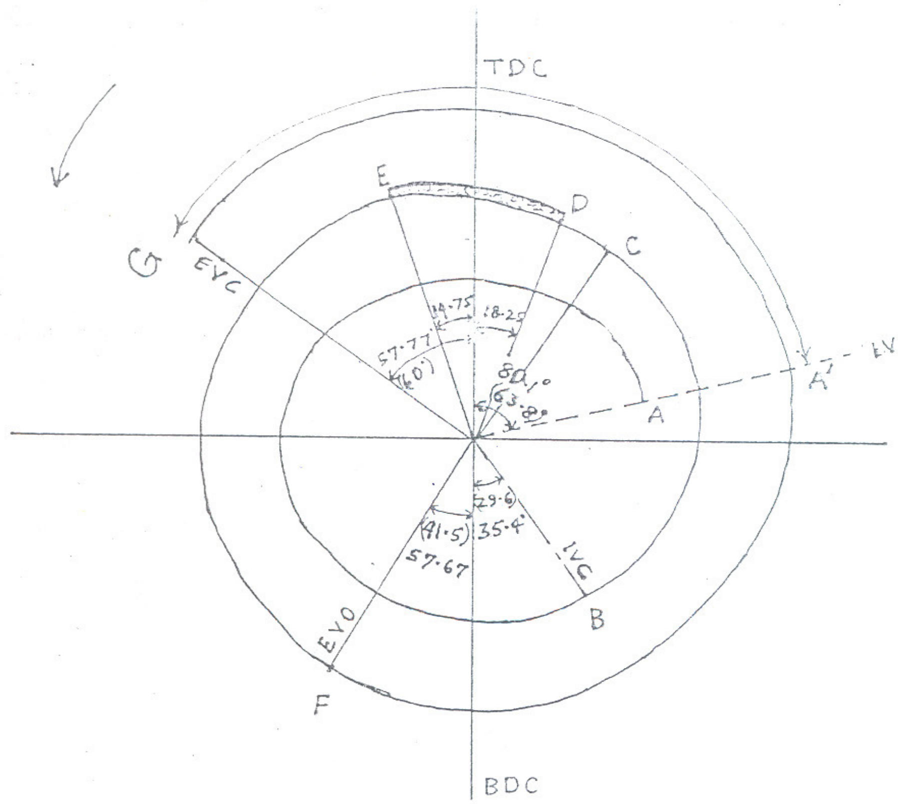
A inlet of fresh air

B discharge of balance of burnt gas

C compression of trapped air

D fuel injection into the compressed hot air.

VALVE TIMING DIAGRAM - 4 STROKE CYCLE:



POINT -A: INLET VALVES OPEN (80.1°BEFORE TDC)

POINT -B: INLET VALVES CLOSE (35.4 AFTER BDC)

PERIOD OF INTAKE : A TO B : (80.1° + 180° + 35.4°) = 295.5°

PERIOD OF COMPRESSION B TO TDC : 180°-35.4° = 144.6°

POINT C : SPILL CUT OFF (25.5° BEFORE TDC)

POINT D : FUEL INJECTION STARTS (18.25 BEFORE TDC)

INJECTION LAG - C TO D : 25.5 - 18.25 = 7.25°

POINT E : TERMINATION OF INJECTION ON FULL LOAD 14.75°

PERIOD OF INJECTION ON FULL LOAD D TO E : 18.25 + 14.75 = 33°

POINT F EXHAUST VALVES OPEN 57.67°BEFORE BDC

PERIOD OF POWER TRANSFER TDC TO F 180-57.77 = 122.33

[illegible] G : EXHAU[illegible]

PERIOD OF EXHAUST F TO G : 57.77 + 180 + 57.77 = 295.54

PERIOD OF SCAVENGING - A' TO G : 80.1 + 57.77 = 137.87

V T DIAGRAM OF WDM_2 (F.E. ENGINE)

Sk: 1.4

As already stated this type of engine needs four strokes of piston or two revolutions of the crankshaft to cover all the events of the cycle Though, superficially it appears that each of the stroke is distinctly for one major event but in actual practice it is not quite so. These events some times over lap between two strokes for better performance.

At the later part of the exhaust stroke when the piston is still moving upwards with exhaust valve already open, the inlet valve opens at $63^{O}48'/80.1^{o}$ before the TDC. The supercharged air at about 1.5 kg/cm^2, above the atmospheric pressure reaches through the inlet valves and pushes out the burnt gas. This process continues upto 60^{o} /57.77^{o} after TDC when the exhaust valve closes.

SUCTION:

When the exhaust valve closed and piston continuing to move downwards, more and more fresh cool air is sucked in through the inlet valves. But the suction does not end just at the BDC and continues up to 29^{o} 40'/35.4^{o} after BDC when inlet valve closes. The extra movement of the crank by this amount provides some more time for more air to find access in cylinder due to "wire drawing" or `interalia' effect. This extra time was not necessary if the size of the valve was as large as the size of the piston. But this is not practicable due to obvious reasons. In order to get more air through the restricted air inlet passage more time is required. Thus the first downward stroke is partly for scavenging and the rest for suction.

COMPRESSION:

Subsequent to the air inlet valve closing at 29^{o} 40'/ 35.4^{o} after BDC the air drawn in the cylinder gets trapped as the exhaust valve also is closed from before. Now with the piston moving upwards in second stroke, compression takes place right up to the TDC but just 18 $1/4^{o}$ before the TDC when the air is well compressed and heated up, combustion of the fuel compressed starts and peak pressure is achieved a little after TDC.

Thus the second stroke (upward stroke) is partly suction and the rest compression in the later part of which the fuel injection also starts.

POWER:

In the 3rd (downward) stroke the high pressure developed in the combustion chamber forces the piston down and is called power stroke. But, a little before the end of this stroke ($41^{O}28'/57.67^{o}$ before BDC) the exhaust valve opens and the burnt gases under some pressure find outlet through the exhaust valve and the residual pressure and energy which was of not much consequence in developing power in the cylinder helps in driving turbo-charger and extra time with exhaust valves open avoids back pressure in the exhaust stroke.

Thus, the third (Downward) stroke is mainly a power stroke and a part in the later and is used for exhaust of burnt gases.

EXHAUST:

After the piston passes the BDC the 4th (upward) stroke starts and physically pushes the burnt gas out. But at a point $63^{O}48'$ before the TDC the inlet valves open with exhaust valve already in open condition. At this stage the pressure of exhaust gas has come down considerably and the pressurized inlet air scavenges the burnt gas. This continues till 60^{o}/ 57.77^{o} after BDC when the exhaust valve closes, thus completing the full cycle. Thus the 4th (upward) stroke is mainly exhaust stroke, but the later part of it is used for scavenging when both inlet and exhaust valves are in open condition. Scavenging has a significant effect on the efficiency of engine. In conventional engine it was $123^{o}48'$ and in fuel efficient it has increased to 137.87^{o}.

From the above, it will be clear that the four strokes of this type of engine covers all the requisite events of Compression Ignition engines.

The valve and fuel injection timing of each engine vary to give optimum output depending on the valve size, cylinder diameter compression ratio, degree of supercharging etc.

Thus, it can be seen that in a four-stroke cycle, every alternate downward stroke is a power stroke, whereas in two-stroke cycle, every downward stroke is a power stroke. This fact sometimes leads to the wrong impression that, for the same size and number of cylinders, a two-stroke cycle engine is capable of developing double the power of the four-stroke cycle engine of same description. This is however not true. The reasons for this are-

1. Only a small part of the downward stroke can be utilized as a power stroke.

2. Greater amount of burnt gas remains in the cylinder mixed with new charged air. The above reasons result in much lesser fuel can be injected per power stroke. Naturally the impression that two stroke cycle engine of same rpm and cylinder size and stroke can develop double the horsepower is not correct. In fact, experience shows that SFC in a two-stroke cycle engine is slightly higher than a four-stroke cycle engine.

CYLINDER ARRANGEMENTS AND ENGINE LAYOUT

Both 2-stroke and 4-stroke cycle can be with many arrangements of cylinders. For rail traction use, in our country, only inline vertical engines, V-engines, and inline horizontal engines are used. Vertical inline engines are used for low hp shunters. V-engines are used for higher hp.

NATURAL ASPIRATION AND SUPERCHARGING

Naturally aspirated engines are those which draw air in the cylinder at a pressure slightly lower than the atmospheric pressure, when partial vacuum is created in the cylinder by outward motion of the piston in the suction stroke, due to inertia of air and unavoidable restriction to flow, resulting in cylinder air pressure being slightly below atmospheric pressure. The demand for more and more power output of the engine, charging of the cylinder with pressurised air had to be resorted to, so that more fuel can be burnt and more power can be produced. Pressure charging of inlet air can be done by -

A engine crankshaft driven centrifugal blower

B roots blower

C exhaust gas driven turbocharger.

When specifically designed for supercharging, power gains can range from 50% to 100%.

ENGINE SIZES AND SPEED

Diesel engines are now put in various types of use depending upon usage; the engines are made in vast range of sizes and speeds. While generally engines are classified in three groups, depending upon the speed and size, there is now well defined demarcation and there can be considerable overlap between adjacent groups. Normally low speed engines are not used for traction purposes, as they are too heavy and bulky, and therefore, they are used mostly for marine work or for stationary duties. The medium As well as high-speed engines are used for rail traction purposes.

FIRING ORDER

In case of four-stroke cycle engine, there is only one power stroke in the four strokes of pistons or every two revolutions of the crankshaft. It is therefore necessary to have a flywheel, to give a 'carry over' for the three "waste" strokes and to ensure a smoother power output. To increase the power output and to make it smoother, multi-cylinder engines are used in which, the firing strokes on different cylinders are suitably spaced in relation to the crank angles so that during the revolutions of the crankshaft, firing of the cylinders takes place one by one at regular intervals.

For even firing in a four-stroke engine, one cylinder must be allowed to fire during each of the four strokes and, therefore the crankshaft arranged at $720^{O}/4=180^{O}$ intervals, and for a sixteen-cylinder engine, it is $720^{O}/16=45^{O}$.

It follows from the above that as the number of cylinders increases, the power output becomes smoother. The firing order is used to prevent damage arising from vibrations setup in the crankshaft, the sequence of firing is so arranged that the vibrations tend to cancel out as far as possible. It may, however, be mentioned that in large engines, running at high speeds, the firing order may not by itself, prevent the buildup of vibrations, and, therefore vibration dampers are mounted on the crankshaft. For our railway standard engines, the following firing order has been prescribed-

WDM_2 LOCOMOTIVES

1R1L-4R4L-7R7L-6R6L-8R8L-5R5L-2R2L-3R3L

WDS6/YDM4 LOCOMOTIVES

1-4-2-6-3-5

COMBUSTION IN DIESEL ENGINE

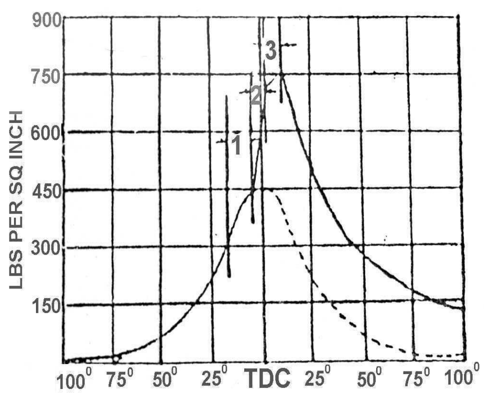
The basic purpose of IC Engine is to develop power by burning fuel. Therefore, good performance of an IC Engine is dependent on how quickly and completely the fuel can be burnt. This burning of hydrocarbons is called combustion, which is a chemical process (oxidation), accompanied by emission of light and heat.

The process of combustion in the compression ignition engine differs widely from that of spark ignition engine. In case of diesel engine only fuel in liquid state is injected at very a high pressure, into highly heated and compressed air in the combustion chamber, the heat of the compressed air starts the combustion process and no agency like electric spark is required.

Process of combustion

If we allow diesel fuel to remain inside a room oxidation will take place, but very slowly. As the temperature of air is raised the process speeds up, ultimately we reach a critical stage where the heat is generated, by oxidation, at a higher rate than it is dissipated. This results in automatic rise in temperature, quicker oxidation and consequent further evolution of heat. This critical temperature is called "Auto-ignition" temperature. This critical temperature of fuel is dependent on factors like type of fuel, pressure etc.

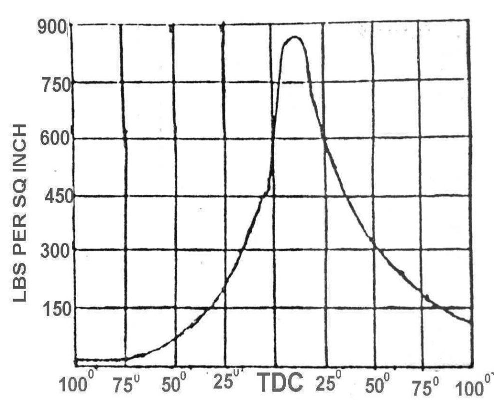
Now when fuel oil at a high pressure is sprayed into the combustion chamber filled with pressurized air, the droplets behave in following manner, of-course in matter of milliseconds. The extreme outer surface of the droplet will immediately start to evaporate, thus surrounding the core with a thin film of vapour. To accomplish this, however, heat must be withdrawn from the air in immediate contact with the droplet in order to overcome the latent heat of evaporation of the liquid. Thus the immediate effect is to reduce the temperature of a thin layer of air surrounding the droplet and some time must elapse before reaching main bulk of air at its vicinity. As soon as this vapour and the air comes in actual contact with it, reach a certain temperature, ignition will take place, although the core is still liquid and relatively cold. Once ignition has been started and a flame established, the heat required for further evaporation would be supplied from that released by combustion. We have, then a core of liquid surrounded by a layer of vapour which is burning as fast as it can find fresh oxygen to keep the process going, and this condition continues unchanged until the whole is burnt.



CRANK ANGLE

SKI 5.1

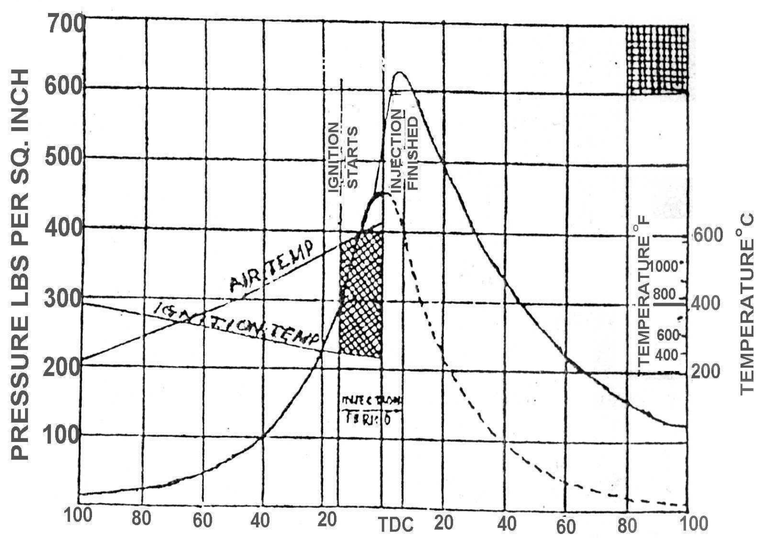
COMBUSTION DIAGRAM (THEORETICAL)



CRANK ANGLE

SKI 5.2

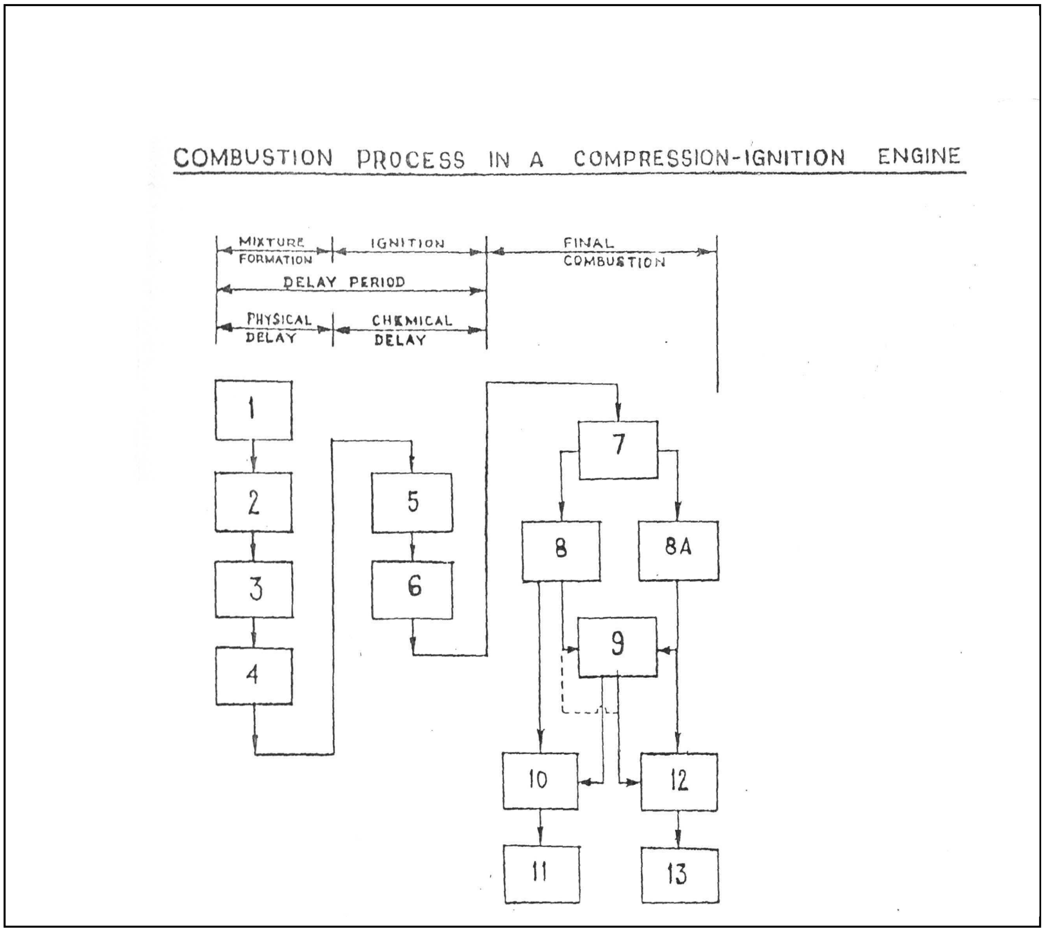
ACTUAL INDICATOR DIAGRAM



DEGREES OF CRANKSHAFT

Sk: 1.5.3

VARIATION IN AIR AND IGNITION TEMPERATURE UP TO THE POINT OF IGNITION



5. Preflame oxidation of fuel Sk: 1.5.4
6. Local ignition
7. Inflamation
8. Oxidation of fuel air mixture/ 8A. Thermal decomposition of fuel
9. Mixing of products of partial oxidation or of thermal decomposition with air.
10. Temp and Oxygen concentration favorable for complete combustion.
11. Products of complete combustion
12. Temp and Oxygen concentration not favorable for complete combustion (chilling, over lean and over rich mixture.)
13. Products of incomplete combustion

Phases of combustion

Though the process of combustion of fuel particles is completed in matter of milliseconds, scientists have analysed the process and have come to conclusion that the process covers the following distinct phases. (See Sk.1.5.1 and 1. 5.2)

1 Delay period (2) Uncontrolled combustion (3) Controlled combustion & (4) Burning in

expansion stroke.

1. Delay period

However small the period may be, for reasons mentioned in preceding paragraphs, some time will elapse between actual injection of fuel in combustion chamber to the inflammation stage when pressure will shoot up. The delay period is affected by factors like -

1. Size of fuel droplet,
2. Air charge temperature at the time of injection,
3. Pressure in combustion chamber,
4. Turbulence of air in combustion chamber,
5. Cetane Number of fuel used,
6. Fuel injection advance.

It is essential to have suitable delay time to facilitate fuel droplets reaching the further ends of combustion chamber and have better fuel air mixture. Less or no delay period will result in incomplete combustion and localised burning near the nozzle tip. Similarly longer delay will lead to Diesel knock and combustion in expansion stage. Hence delay period should be controlled within optimum range.

2. Uncontrolled combustion

This phase is often termed as flame spread. It is the period of rapid combustion of fuel already accumulated in the delay period and partly also those injected during the controlled combustion period. Since the charge has already accumulated and exploded giving sudden rise of pressure, it is called uncontrolled combustion. This phase should start just before the piston reaches top dead centre and should be completed little after top dead centre.

The factors which affect this phase are

(a) Duration of Phase-I
(b) The items which control the Phase-I.

In other words, longer the delay period, more will be the accumulated fuel charge and higher will be the pressure rise.

3. Controlled combustion

After the steep rise in pressure comes to an end, the rate of increase of pressure comes down and the curve stoops down comparatively. This controlled combustion phase is from the end of uncontrolled combustion phase to a little after the end of fuel injection. The reasons for this portion of curve being less steep are that in this phase, unlike the previous phase the fuel which is coming in is burning and that the piston has started residing resulting in reduction in the rate of increase of pressure rise. The aspects having effect on this phase are:

a) Duration of phase-I and,
b) Fuel injection timing,
c) Factors which control phase-I and II

4. Combustion in expansion stroke:

This phase is generally not taken into account, as in ideal conditions this should not exist. But never the less it exists and in this period unburnt fuel gets burnt as it finds oxygen. But this does not contribute to engine output and hence the lesser it is, the better.

Though theoretically the phases of combustion have been shown distinct from each other as shown in Sk.1.5.1, the actual indicator diagram shows the combustion curve as shown in

Sk.1.5.2.

Sk.1.5.3. shows that with the increase of pressure the air temperature increases and the auto ignition temperature level goes down slightly.

The flowchart of combustion as shown in Sk.1.5.4 indicates that delay period is sub-divided in two parts i.e. physical delay and chemical delay. It can also be seen that due to temperature going higher than what is conducive to proper combustion, and for some other reasons, fuel vapours crack up into elements, a portion of which again take part in the process of combustion.

It will be appreciated that the whole process is completed in about 0.005 seconds and this highly limited time has been a bar on further detailed analysis of this stage.

QUALITY OF AIR REQUIRED AND TURBULANCE: -

Since power of an engine is largely dependent on the quality of air it inhales and compresses per cycle, it is necessary to have an idea about the quantity of air required for proper combustion. It is known that atmospheric air consists of 3.32 parts of nitrogen by weight of oxygen to produce 4.32 parts by weight of air. In other words in order to get 1 kg of oxygen we have to get 4.32 kg of air.

With the; help of simple chemical formula we can find out the quantity by wt. of air required to burn combustible substances. The diesel fuel is nothing but a combination of various groups of hydrocarbons. Though there are 29 and odd varieties of hydrocarbons presence of a few varieties is predominate in particular, types of fuel oil. It has been found that for burning l kg of HSD oil a theoretical quantity of approximately 18-kg of air is required. But the entire quantity of air pressed into the combustion chamber does not come into play in the process of combustion and as such an excess quantity i.e. 28 kg approximately is given for every kg of fuel burnt.

But providing excess amount of air alone will not suffice for having complete combustion. If the air within the cylinder was motion-less it would be evident that only one small portion of the fuel would find enough oxygen. Since it is impossible to distribute fuel droplets uniformly to fill up the entire combustion chamber space. Considerable relative motion between air and the fuel is necessary to ensure not only continuous supply of fresh air to each burning particle but also to sweep away the products of combustion which may otherwise have a tendency to suffocate combustion. Therefore, the rate of burning depends to a great extent on the rate at which the products of combustion can be removed from the outer surface of the particles so that the fuel vapour comes in contact with fresh hot air and thereby get heat and oxygen. In other words it depends upon the rate at which burning droplets are moving across the air and also air across the droplets.

Combustion chamber design:

The main aim of combustion chamber design is to effect rapid and complete combustion of fuel by creating high relative velocity or turbulence thus resulting in thorough mixing of air and fuel.

The above effect is achieved by following methods: -

(a) Giving a particular shape to the inlet air passage so that the airflow is so directed that it has maximum effect in moving across the fuel particles. This is called in-take induced "Swirl".

(b) By giving such valve angle that would have max. Possible airflow which would cut across fuel particles in the best manner possible. Use of masked valve in combination with directional part is also resorted to for this purpose.

(c) The piston crown is given particular shape to aid the swirl of air. This is some times called piston induced "Squish".

(d) Diesel designers working in close co-operation with fuel injection engineers have produced many successful conformations for combustion chambers. The type used is also dependent upon engine size, speed, type and application. Combustion chamber types being produced today may be classified as :-

1. Pre-combustion chamber or quiescent pre-combustion chamber.
2. Air cell or energy cell
3. Turbulent chamber of turbulent pre-combustion chamber
4. Open combustion chamber with direct injection

But with the advent of highly super-charged engines it has been found that excepting for providing directional port and slight concave shape of cylinder head surface and piston crown in an open combustion chamber no other complication is necessary.

All the standard diesel locos of Indian Railways are provided with this type of combustion chamber.

WDM 2 DIESEL LOCOMOTIVE ENGINE DATA

In WDM2 class locomotives, ALCO design 251B model 16-cylinder exhaust gas turbo-supercharged closed circuit water cooled, compression ignition medium speed four-stroke diesel engine is used. The engine's general characteristic and ratings are given below-

CYCLE	*4 STROKE CYCLE*
ASPIRATION	*TURBOSUPERCHARGED WITH CHARGE AIR COOLING*
BORE	*9 INCHES (228 mm)*
STROKE	*10.5 inches (267 mm)*
COMPRESSION RATIO	
CONCAVE CROWN STYLE	*12.5:1*
FLAT CROWN STYLE	*11.5:1*
HORSEPOWER (GROSS)	*2600 BHP*
ENGINE SPEED	*1000 RPM (FULL LOAD)*
	400 RPM (IDLE
PISTON SPEED (MEAN)	*9.89 m/sec*
BMEP	*13.57 kg/cm^2*
SWEPT VOLUME PER CYLINDER	*10.5 ltrs.*
WEIGHT (DRY ENGINE)	*19026 kg*

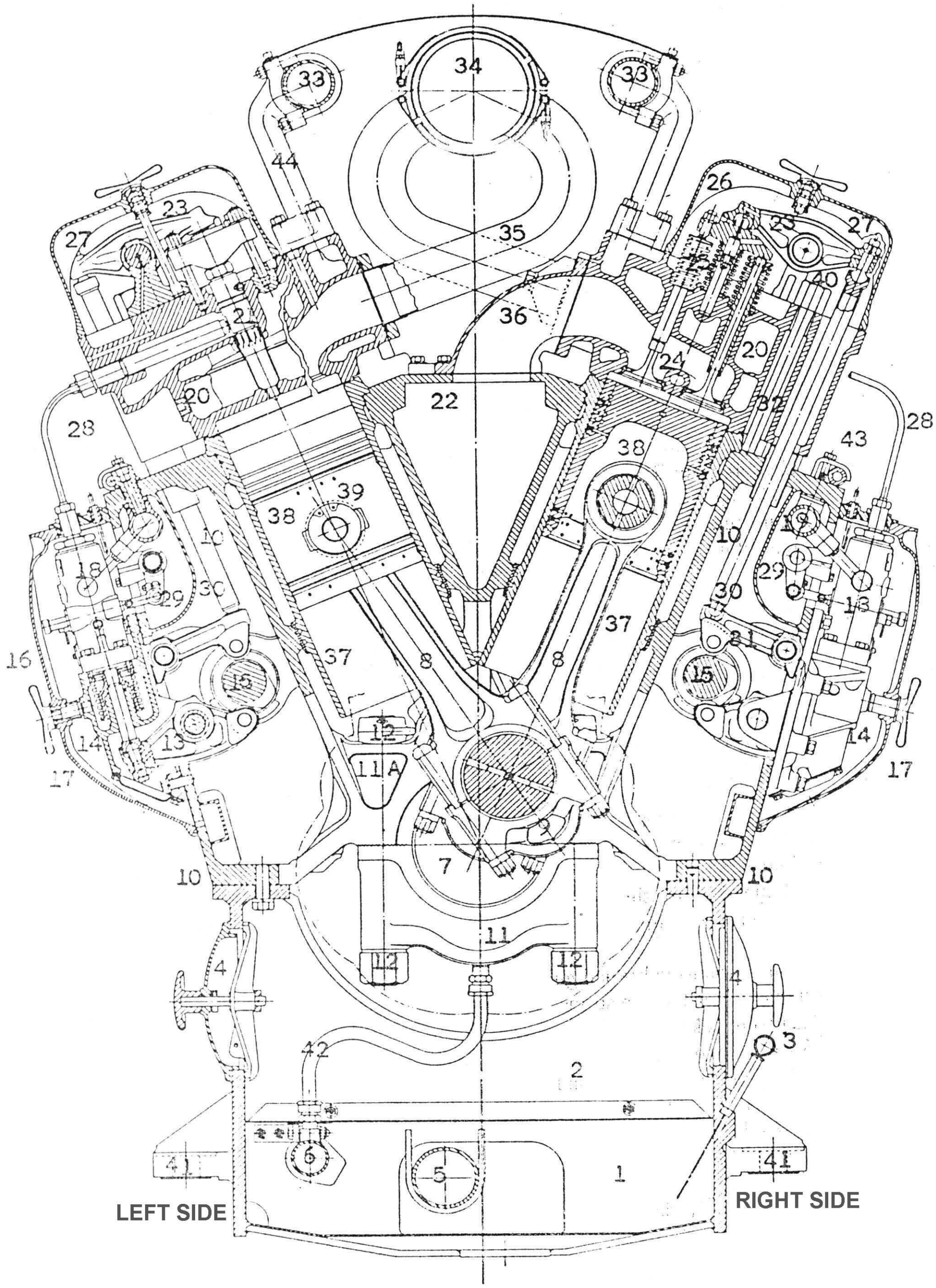
ENGINE EQUIPMENT LAYOUT-WDM2 EXTERNAL VIEW (Fig: Sk-1.6)

1. Base engine/ crankcase /oil sump
2. Sump
3. Oil level depth gauge.
4. Crankcase inspection door
5. Lube oil pump
6. Lubricating oil main header flange
7. Crank shaft
8. Connecting rod
9. Lubricating oil pump with relief valve
10. Engine block
11. Main bearing cap
12. Main bearing nut
13. Fuel Pump lifter
14. FP support
15. Camshaft
16. Lube oil pipe
17. FP cover
18. Fuel pump
19. Water raiser pipe
20. Cyl.head
21. Exhaust manifold
22. V-channel
23. Rocker arm
24. Inlet valve
25. Fast coupling expresser drive
26. Valve lever casing
27. Adjusting screw
28. HP tube
29. Control shaft
30. Push rod
31. Push rod lifter
32. Cyl.head stud
33. Water header
34. Exhaust manifold
35. Exhaust manifold arm
36. Inlet elbow
37. Liner
38. Piston
39. Piston pin
40. FIP support

41 Free end foundation bolt

42 S-pipe

44 Water riser



ENGINE EQUIPMENT LAYOUT
251-B (WDM$_2$)

16 CYLINDER DIESEL ENGINE CROSS SECTION

Sk: 1.6

SUMMARY

Diesel Engine is an Internal Combustion, Compression Ignition Engine. Operation Cycle of the Diesel Engine consist of the functions like Suction, Compression, Firing, Expansion and Exhaust. Depending on the number of strokes required to complete one working cycle they are divided into two groups – 2 Stroke & 4 Stroke cycle Engine. Valve Timing Diagram of 4 Stroke and 2 Stroke Engine indicates the correct opening and closing period of Valves and Fuel Injection timing, hence, it correctly explains the duration of different functions of the Engine. Diesel Engines are further classified into Inline or V-shaped Engine, Naturally Aspirated or Supercharged Engine, depending upon the cylinder arrangement on the block and the air induction system. Supercharging means charging of high-pressure intake air into the cylinder to improve the efficiency and power output of the Diesel Engine. Supercharging can be done by any of the methods, through (1) engine crankshaft driven centrifugal blower/ roots blower (2) exhaust gas driven turbocharger. Firing Order determines the sequence of firing at different cylinders of a multi cylinder Engine. Correct sequencing of Firing Order reduces the vibration of a multi cylinder engine upto a large extent. Combustion in Diesel Engine explains the process of combustion . Different phases of combustion are- Delay Period, Uncontrolled Combustion, Controlled Combustion and Burning in expansion stroke. These phases determine the shape of the diesel cycle of the engine. Quality of air with turbulance is a vital factor for effective combustion. Turbulance is created by suitably designing the combustion chamber. A typical WDM2 Diesel Locomotive Engine Data is being included for better understanding.

SELF ASSESSMENT

1. What do you understand by a Two stroke and a Four stroke cycle engine?
2. What do you learn from the Valve Timing Diagram?
3. What is the difference between a natural aspirated and a supercharged engine? What are the various methods of supercharging?
4. What is the importance of firing order of a multi-cylinder engine? Mention the firing order of WDM2 locomotive engine.
5. What are the phases of combustion? What do you understand by Delay in Combustion? Which factors affect the delay period?
6. What is the stroke length and compression ratio of WDM2 locomotive engine?

Measures and Units: cetane number

[**Etymology:** refers to the chemical used] *automotives* A measure of the 'knock' or compressive ignitability of a fuel, being the percentage by volume of the chemical cetane, which, when blended with methylnaphthalene, gives a like performance. Cetane rating applies to fuel for diesel engines, which, unlike gasoline engines, depend on compressive ignition of fuel. However, for adequate performance the ignition must not occur too readily; a cetane rating above 40 is typically required. Compare octane number.

Wikipedia: cetane number

Cetane number or CN is a measure of the combustion quality of diesel fuel via the compression ignition process. Cetane number is a significant expression of diesel fuel quality among a number of other measurements that determine overall diesel fuel quality. Cetane number of a fuel is defined as the percentage by volume of normal cetane in a mixture of normal cetane and alpha-methyl napthalene which has the same ignition characteristics (ignition delay) as the test fuel when combustion is carried out in a standard engine under specified operating conditions.

Cetane number is actually a measure of a fuel's ignition delay; the time period between the start of injection and start of combustion (ignition) of the fuel. In a particular diesel engine, higher cetane fuels will have shorter ignition delay periods than lower cetane fuels. Cetane numbers are only used for the relatively light distillate diesel oils. For heavy (residual) fuel oil two other scales are used CCAI and CII.

Generally, diesel engines run well with a CN from 40 to 55. Fuels with higher cetane number which have shorter ignition delays provide more time for the fuel combustion process to be completed. Hence, higher speed diesels operate more effectively with higher cetane number fuels. There is no performance or emission advantage when the CN is raised past approximately 55; after this point, the fuel's performance hits a plateau. In North America, diesel at the pump can be found in two CN ranges: 40-46 for regular diesel, and 45-50 for premium. Premium diesel may have additives to improve CN and lubricity, detergents to clean the fuel injectors and minimize carbon deposits, water dispersants, and other additives depending on geographical and seasonal needs.

In Europe, diesel cetane numbers were set at a minimum of 49 in 1994 and 51 in 2000.

Dimethyl ether may prove advantageous as a future diesel fuel as it has a high cetane rating (55) and can be produced as a biofuel.

Alkyl nitrates and di-tert-butyl peroxide are used as additives to raise the cetane number.

Comparison to octane rating

Cetane rating of diesel is not equivalent to gasoline's octane rating. This is because gasoline's desirable property is to resist autoignition to prevent engine knocking whereas diesel's desirable property is to autoignite.[1]

Chemical relevance

Cetane is an alkane molecule that ignites very easily under compression, so it was assigned a cetane number of 100. All other hydrocarbons in diesel fuel are indexed to cetane as to how well they ignite under compression. The cetane number therefore measures how quickly the fuel starts to burn (auto-ignites) under diesel engine conditions. Since there are hundreds of components in diesel fuel, with each having a different cetane quality, the overall cetane number of the diesel is the average cetane quality of all the components. There is very little actual cetane in diesel fuel.

Measuring cetane number

To measure cetane number properly is rather difficult, as it requires burning the fuel in a special, hard-to-find, diesel engine called a Cooperative Fuel Research (CFR) engine, under standard test conditions. The operator of the CFR engine uses a hand-wheel to increase the pressure within the cylinder of the engine until the time between fuel injection and ignition is 2.407ms. The resulting cetane number is then calculated by determining which mixture of cetane (hexadecane) and isocetane (2,2,4,4,6,8,8-heptamethylnonane) will result in the same ignition delay.

Another reliable and more precise method of measuring the cetane number of diesel fuel is the Ignition Quality Tester (IQT^{TM}). This instrument applies a simpler, more robust approach to CN measurement than the CFR. Fuel is injected into a constant volume combustion chamber in which the ambient temperature is approximately 575°C. The fuel combusts, and the high rate of pressure change within the chamber defines the start of combustion. The ignition delay of the fuel can then be calculated as the time difference between the start of fuel injection and the start of combustion. The fuel's derived cetane number can then be calculated using an empirical inverse relationship to ignition delay.

Another method that fuel-users control quality is by using the Cetane index (CI), which is a calculated number based on the density and distillation range of the fuel. There are various versions of this, depending on whether you use metric or Imperial units, and how many distillation points are used. These days most oil companies use the '4-point method'. However, CI can not be used with cetane improver additives.

The industy standards of measuring cetane number is ASTM D-613 (ISO 5165) and D-6890.